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Infestation of the woodwasp *Tremex apicalis* Matsumura (Hymenoptera, Siricidae) on the large-leaf dogwood *Swida macrophylla* (Wall.) with biological notes on its parasitoid wasps

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Abstract

The woodwasp *Tremex apicalis* (Hymenoptera: Siricidae) infesting a decayed stand of *Swida macrophylla* (Cornales: Cornaceae) was found in Honshu, Japan. *S. macrophylla* was newly recorded as a host tree of the woodwasps. We observed oviposition behavior of *T. apicalis* on the tree trunk on May, 2015. In addition, prepupae and pupae of *T. apicalis* were observed in the wood on April, 2016. However, no larvae of *T. apicalis* were found at that time. This suggests that *T. apicalis* requires one year from egg to pupation. Parasitoid wasps, *Ibalia japonica* (Hymenoptera: Ibaliidae) and *Megarhyssa* spp. (Hymenoptera: Ichneumonidae), were also observed on the trunk (oviposition behavior of adult females) and in the wood (pupae and newly emerged adults). Because *Ibalia* and *Megarhyssa* are known as larval parasitoids of woodwasps and there were no other insect species in the wood, we conclude that these wasps are parasitoids of *T. apicalis* larvae. These parasitoids appear to be major natural enemies of *T. apicalis* larvae in the study site.

Keywords

Cerrena unicolor, horntail, *Ibalia japonica*, Ibaliidae, Ichneumonidae, *Megarhyssa*, oviposition behavior, wood borer, natural enemy

Introduction

Woodwasps (= horntails) (Hymenoptera, Siricidae) are common forest pests with some species known as serious pests of trees. Some introduced woodwasps cause serious damage to forests, regardless of their extent of damage in the native habitat (Morgen 1968). All woodwasps belonging to the subfamily Tremecinae infest broad-leave trees (Okutani 1967) and female wasps deposit their eggs into the wood with their ovipositors. At least females of some species of *Tremex* (Hymenoptera: Siricidae: Tremecinae) carry symbiotic fungi in their mycangia and transfer it to trees during oviposition (Stillwell 1964, Tabata and Abe 1995, Pažoutová and Šrůtka 2007). Hatched larvae then consume the wood with the fungus. This woodwasp-fungus association damages the tree, and in some cases kills the tree (Morgan 1968).

Tremex apicalis Matsumura is distributed in Japan (Okutani 1967), China (Maa 1949) and Korea (Lee et al. 1998). This species infests at least five species of four families of broadleaf-trees (Kono and Sugihara 1939, Maa 1949, Okutani 1967, The Japanese Society of Applied Entomology and Zoology 2006), including the ornamental plant Somei-yoshino *Prunus yedoensis* and maple trees *Acer* spp. in Japan (Okutani 1967). These trees are important garden trees in Japan and have also been introduced into many countries. Therefore, these woodwasps are potential pests of forests and gardens in not only Japan but also in temperate regions worldwide. For protection including biocontrol, understanding the biology of these pests and their natural enemies is important. In biocontrol of woodwasps, parasitoid wasps are one important natural enemy (Morgen 1968, Coyle and Gandhi 2012, Schiff et al. 2012, Tabata et al. 2015). In fact, Ichneumonidae (especially Rhyssinae) and Ibaliidae contribute to the biocontrol of woodwasps (Coyle and Gandhi 2012). However, the host-parasitoid relationships between *T. apicalis* and its parasitoids are poorly known and the biology of *T. apicalis* is largely unknown.

In May 2015, we found a large-leaf dogwood, *Swida macrophylla* (Wall.) (Cornales: Cornaceae) infested by *T. apicalis* in Ibaraki, Honshu, Japan. We then observed the oviposition behavior of *T. apicalis* and its parasitoid wasps. Fortunately, we were able to obtain permission to split the wood, and observe the wasp biology inside the wood the next spring. The results of these observations provide new information on the host-parasitoid relationships and biology of *T. apicalis* and its parasitoids. This information may contribute to the protection of Japanese garden plants. In this paper, our observations on these species are described.

Materials and methods

Study site and host tree

A field survey of *T. apicalis* was carried out at the Botanical Garden in the Agricultural and Forestry Research Center (36°07'10"N; 140°05'50"E (DMS), ca. 25 m a.s.l.),

University of Tsukuba, Ibaraki Prefecture, Honshu, Japan. In the study site, we found one *S. macrophylla* tree with numerous emergence holes of *T. apicalis* in the trunk on May 6, 2015 (Fig. 1). The *S. macrophylla* tree was approximately 9 m in height and 40 cm in diameter at breast height.

Field observations and wood splitting

We observed the target *S. macrophylla* tree from 11:30 to 12:30 on May 6, 2015. Species of hymenopteran insects that landed on the *S. macrophylla* tree and their behavior were recorded for 60 min. From the observation day until March 1, 2016, we observed the infested tree approximately once a week whether or not adult woodwasps visited.

The infested tree was felled with a chainsaw on March 8, 2016 and the wood kept outside. The infested part, total 14.725 kg wet wt with woodwasp emergence holes, was split using a 7.2 ton electric wood splitting machine (E'Z - Splitter IG-700A, Husqvarna Zenoah Co. Ltd) and a hatchet on April 10, 2016. Insect species and their stages were tallied.

Voucher specimens are deposited in the Laboratory of Applied Entomology and Zoology, University of Tsukuba (Tsukuba City, Japan) and Kanagawa Prefectural Museum of Natural History (Odawara City, Japan).

Figure 1. Infested *Swida macrophylla* at Botanical Garden, University of Tsukuba, Honshu, Japan. **a** a decayed *S. macrophylla* infested with *T. apicalis* **b** *T. apicalis* adults and their emergence holes (red arrows) on the tree trunk. Scale lines = (**a**) 100 cm; (**b**) 100 mm.

Results

In the field survey, we observed a total of 10 *T. apicalis* (3 males, 7 females) and 24 parasitoid wasps, i.e. *Ibalia japonica* Matsumura (Hymenoptera: Ibaliidae), *Megarhyssa jezoensis* (Matsumura) and *M.* sp.1 (Hymenoptera: Ichneumonidae), that landed on the tree (Fig. 2, Table 1). In addition, six dead bodies of female *T. apicalis* were observed on the tree trunk. Two of them were whole bodies and the others were only ovipositors with abdomens attached to the trunk (Fig. 2b). Some females of the hymenopteran species were observed inserting their long ovipositors into the trunk (Fig. 2). Of the three males of *T. apicalis*, two males were mounting the female on the trunk. One female was observed inserting her ovipositor into the trunk with a male on her back. No *T. apicalis* adults were observed on the trunk between June 2015 until March 2016.

From the *S. macrophylla* wood, 35 prepupal or pupal *T. apicalis* and 16 pupal or adult parasitoids were obtained (Table 2, Figs 3, 4). Basidiocarps of the fungus *Cerrena unicolor* were observed on the bark of the infested wood and the inside of the wood was partly discolored (Fig. 3a, b). All woodwasp prepupae and pupae collected, and their larval tunnels were found in the discolored part of the wood (Fig. 3c). All *T. apicalis* constructed longitudinal pupal chambers in the wood (Fig. 3c). We also found pupae and adults but no larvae of *I. japonica* and *Megarhyssa* spp. in the wood (Table 2). All collected prepupae and pupae of *T. apicalis* were individually stored in plastic bags in the laboratory. Of nine *T. apicalis* prepupae, only one pupated within one week after collection, while all others died. The pupated *T. apicalis* also died after five days. Four pupae of the 26 collected pupae emerged between 2-4 weeks after collection, while all others died.

Table 1. Number of hymenopteran insects that landed on decayed *S. macrophylla*.

	male	female	Total
Tremex apicalis	3	7	10
Ibalia japonica	9	5	14
Megarhyssa spp.	2	8	10
M. jezoensis female	-	5	5
M. sp.1 female	-	3	3
M. spp. male[a]	2	-	2

[a] males not identified to species.

Table 2. Number of hymenopteran insects found in the *S. macrophylla* wood.

	prepupa	pupa	adult	total	propotion
Tremex apicalis	9	26[a]	0	35	0.69
Ibalia japonica	0	3	0	3	0.06
Megarhyssa spp.	0	2	11	13	0.25
M. jezoensis female	0	0	4	4	
M. sp. 1 female	0	1	4	5	
M. spp. male [b]	0	1	3	4	

[a] 14 males, 11 females and 1 unknown.

[b] males not identified to species.

Figure 2. Hymenopteran insects landing on and inserting their ovipositor into the *S. macrophylla* tree trunk. **a** *T. apicalis* female **b** *T. apicalis* ovipositor with abdomen inserted into the wood **c** *I. japonica* female **d** *M. jezoensis*. female. Scale lines = 10 mm.

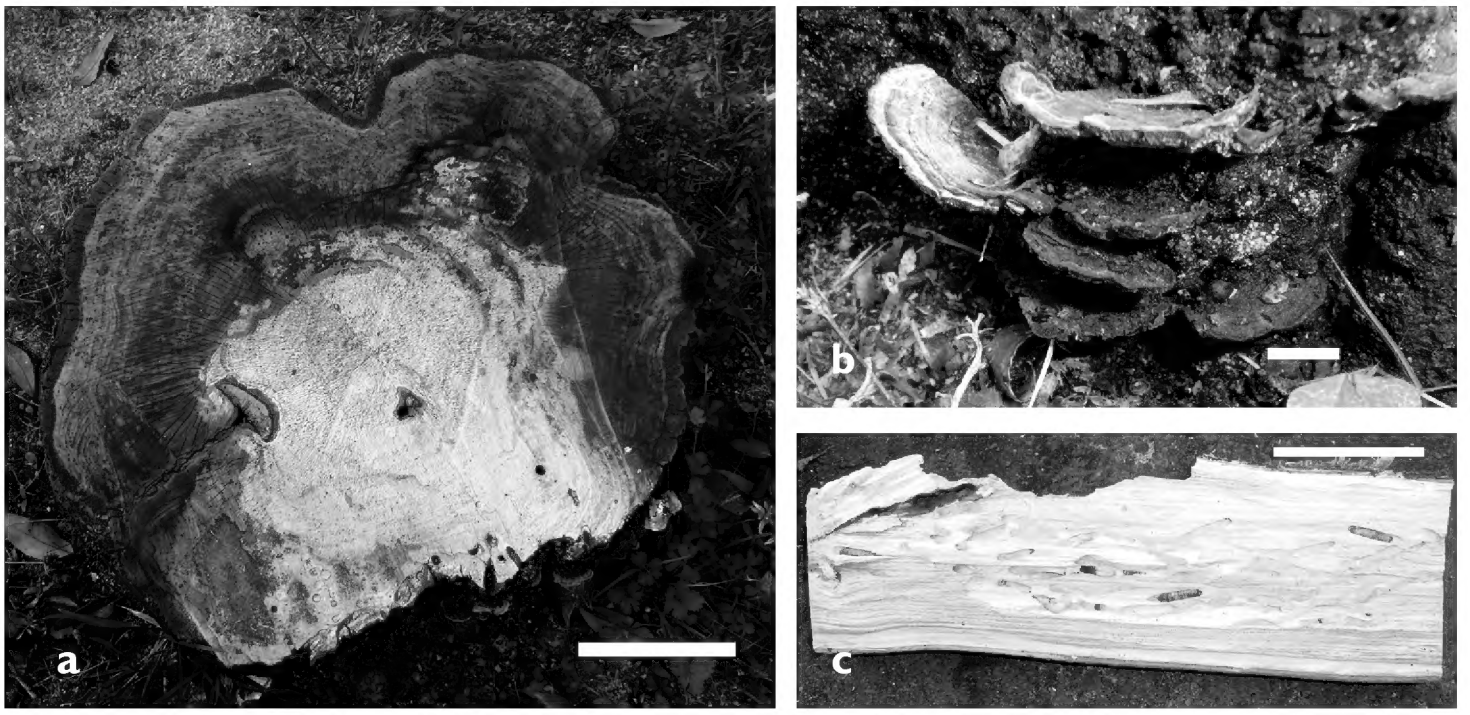

Figure 3. *S. macrophylla* wood infested with *T. apicalis*. **a** Wood discoloration in the cross section with *T. apicalis* infestation **b** Basidiocarp of *Cerrena unicolor* in the wood infested with *T. apicalis* **c** Longitudinal section through stem of the wood infested with *T. apicalis* and woodwasp larvae, pupae and larval tunnels. Scale lines = (**a, c**) 100 mm; (**b**)10 mm.

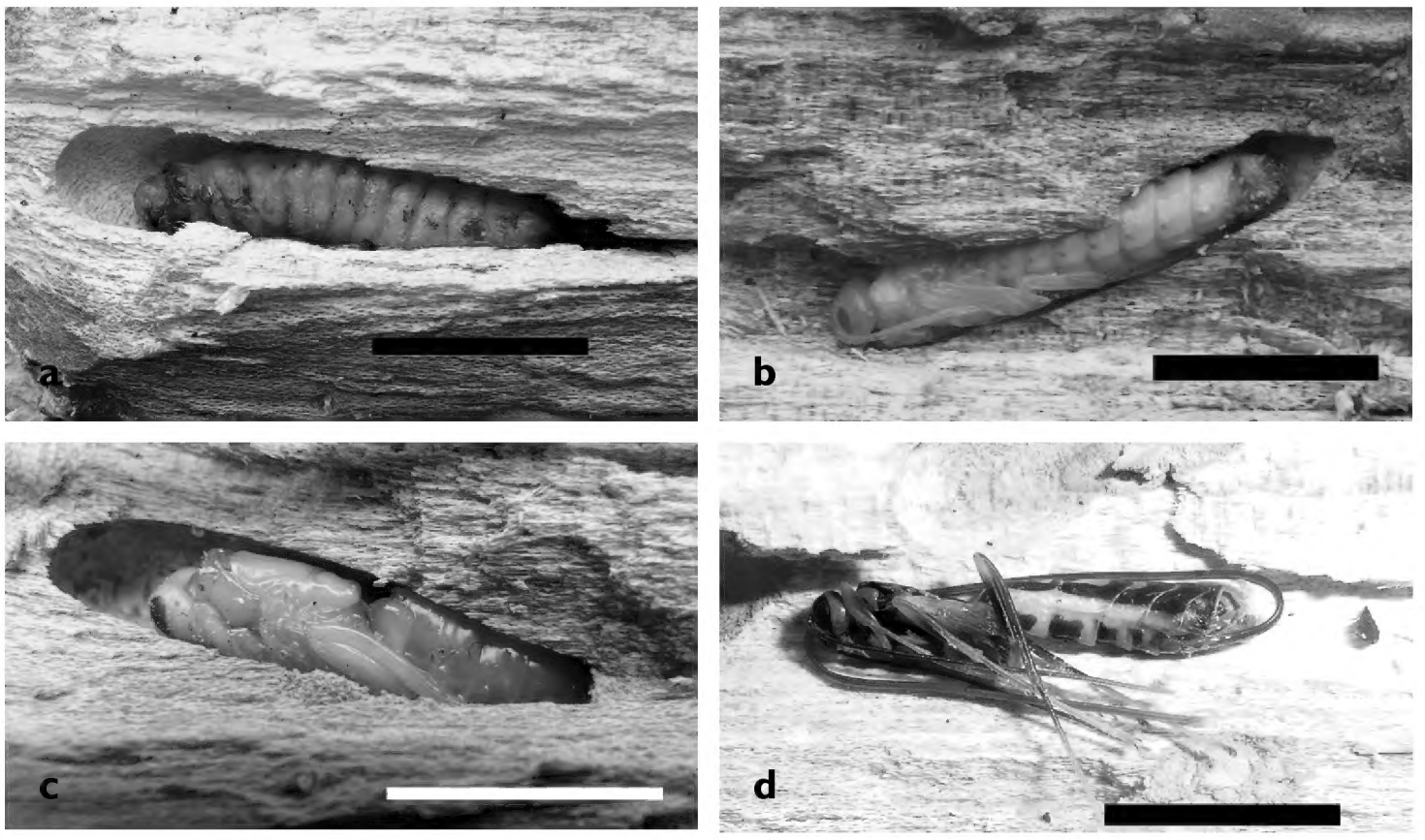

Figure 4. Hymenopteran insects found in *S. macrophylla*. **a** *T. apicalis* prepupa **b** pupa of *T. apicalis* female **c** *I. japonica* pupa **d** pupa of *M.* sp.1 female. Scale lines = 10 mm.

Discussion

In this study, we observed oviposition behavior of *T. apicalis* on a *S. macrophylla* tree, and the presence of prepupae and pupae in the tree. The order Cornales, which includes *S. macrophylla*, is a newly recorded host of *T. apicalis*.

In a field survey, many ovipositors of *T. apicalis* were observed on the trunk of a *S. macrophylla* tree. Yamazaki and Matsumoto (2009) also observed ovipositors with abdomens on host wood in a related species *T. longicollis* Konow. They suggested that this phenomenon was caused by predation during oviposition. However, we observed two females of *T. apicalis* that died without external damage. Not only predation but also other physiological factors may cause the death of *T. apicalis* during oviposition. In other woodwasp species, female parasitoids of *Ibalia* spp. oviposit their eggs on woodwasp larva by using the oviposition holes created by the female woodwasps (Spradbery 1970, 1974). The dead body of female *T. apicalis* attached to the wood may indicate the female is defending its larvae from ibaliid parasitoids.

No *T. apicalis* adults were observed on the tree trunk from June 2015 until the following spring. Hence *T. apicalis* is univoltine, active mainly in the spring. After wood splitting, we observed prepupae and pupae of *T. apicalis* but no larvae in the wood. This suggests that *T. apicalis* takes almost one year to develop from egg to pupal stages. Since most of the collected prepupae died after wood splitting, we were unable to observe whether they would emerge within this year.

All *T. apicalis* prepupae and pupae were found in the discolored part of the wood and the wood had basidiocarps of *Cerrena unicolor* on the bark (Fig. 3). Adult females of Siricidae carry the symbiotic fungus in their mycangia, and inject it during oviposition so hatched larvae can feed on wood infested with fungi (Tabata 2003). Some *Tremex* woodwasps, i.e. *T. longicollis* and *T. fuscicornis*, are associated with the fungus *C. unicolor* (Tabata and Abe 1995, Pažoutová and Šrůtka 2007). *T. apicalis* probably uses *C. unicolor* as a symbiotic fungus. Identification of the fungus in the woodwasp mycangia should be carried out in future studies.

Hymenopteran parasitoids, *I. japonica*, *M. jezoensis* and *Megarhyssa* sp. 1, were also observed in/on *T. apicalis* infested *S. macrophylla*. We were unable to observe the larvae that parasitized *T. apicalis* larvae. However, all known ibaliids are primary solitary, koinobiont endoparasitoids of woodwasps (Liu and Nordlander 1994, Choi et al. 2013), especially species of the subgenus *Tremibalia* that includes *I. japonica*, and parasitize Tremicinae wood wasps (Liu and Nordlander 1994). Similarly, *Megarhyssa* are idiobiont ectoparasitoids of woodwasps and other hosts in the same habitat (Quicke 2015). Since we observed no other woodwasp species and no other insects in the wood, we conclude that these wasps parasitize *T. apicalis* larvae. To our knowledge, *I. japonica* is the second ibaliid parasitoid species of *T. apicalis*, the first being *I. takachihoi* (Kim 1971). *T. apicalis* is the first host species of *I. japonica*. Some species of *Megarhyssa* are known as parasitoids of *Tremex* (Heatwole and Davis 1965, Kim 1971, Yamazaki and Matsumoto 2009, Pook et al. 2016). *M. jezoensis* has been reported as parasitoids of *T. apicalis* in Korea (Kim 1971). In our survey, *Megarhyssa* spp. were the dominant parasitoid wasp in the infested wood (Table 2).

Because *Ibalia* and *Megarhyssa* are known as solitary parasitoids, their proportion in the wood (Table 2) can be interpreted as the parasitism rate. According to the data in Table 2, the parasitism rate of *T. apicalis* larvae by all larval parasitoids species is approximately 31.4 %. These parasitoids appear to be the major natural enemies of *T. apicalis* larvae and may regulate woodwasp populations in the study site.

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